Agronomy Research **19**(S2), 1087–1098, 2021
https://doi.org/10.15159/AR.21.089

Thermal comfort assessment in a typological non-isolated maternity pig sheds with different types of farrowing systems

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Received: February 1st, 2021; Accepted: May 8th, 2021; Published: May 19th, 2021

Abstract. Swine facilities in tropical climates, especially the maternity, have worked with typological systems that have been little studied to determine the influence of the type of farrowing on microenvironmental conditions and its effect on both the sows and the piglets' physiological parameters. Therefore, the aim of the research was evaluate the thermal environment (Temperature Humidity Index - THI and Radiant Thermal Load - RTL) and its influence on some physiological parameters (respiratory frequency - RF and rectal temperature - TRectal) in the sows and piglets in two different types of farrowing systems (Traditional and Slatted), in a typological swine facility located in tropical climates in Colombia. The findings showed that in the two systems, both for sows and piglets, the type of farrowing system did not generate significant differences in the physiological responses RF and TRectal. Also, the RTL did not show significant differences in the two types of farrowing system at the piglets and the sows' level, without exceeding the maximum allowed levels. Temperature-Humidity Index was above the threshold during all experimental time, being slightly higher at the piglets' level with Slatted systems. These results show that the type of floor has little impact on the conditions of animal thermal comfort at the sows and piglets' level. However, variables like low-temperature, low radiant energy exchange, and high humidity, which were found mainly at the piglets' level, could have the highest incidence for not achieving a suitable microenvironment. This means that almost all Colombian pig farming facilities require a redesign of their farrowing system to guarantee better thermal conditions for both piglets and sows.

Key words: comfort Index, farrowing systems, swine facility, tropical country.

INTRODUCTION

In the world and especially in tropical countries such as Colombia, pig farming has shown a process of expansion within the economy of each country, with signs of dynamism reflected in the sustained increase in slaughter (Díaz et al., 2011), the exponential increase in the number of animals in recent years and the growing demand for consumption.

However, few studies that show the spatial variability of the thermal conditions of the typological maternity sheds have been made, unlike studies that have been carried out in other non-tropical countries like the ones carried out by Gourdine et al. (2006) and in tropical and subtropical areas such as those of Ek et al. (2016); Vieira et al. (2010), Campos et al. (2009); Sampaio et al. (2004) among others.

Nowadays, the public demand for more welfare-friendly swine systems has resulted in a ban on individual housing of sows for the majority of gestation in the EU (Council Directive 2001/88/EC), which has become a worldwide trend. However, according to Van Nieuwamerongen et al. (2014), most sows are still individually confined in crates during farrowing and lactation. Several studies have investigated alternative farrowing systems over the years, such as group housing of sows during lactation; however, it is more challenging to keep the environmental conditions to achieve good animal comfort in this type of housing.

Matthew & Timothy (2017) point that initial studies of heat stress primarily focused on lactating sows because lactation is a period of high metabolic load that sensitizes individuals to environmental temperature. Heat-stressed sows and piglets typically reduce their feed intake (Renaudeau et al., 2012; Ek et al., 2016).

Thus, in pork production facilities, the greatest challenges are to maintain optimal conditions of thermal comfort in farrowing systems (Tummaruk et al., 2010; Osorio et al., 2017; Castrillón et al., 2020), since there are two different thermal environment conditions, one for piglets and another for sows. These challenges have allowed some studies to be carried out in these areas, such as those carried out by Vieira et al. (2010), Machado et al. (2016) and de Oliveira junior (2011), as well as others by Phillipe et al. (2011) who evaluated the effect of farrowing on the generation of gases such as ammonia.

When subjected to severe heat stress and the heat load increases, animals try to sustain homeothermy by using internal physiological means to re-establish a thermal balance (Marai et al., 2002). The respiratory frequency (RF, %) and rectal temperature (TRectal, °C) reflect the physiological mechanism for heat dissipation.

One of the methods used to assess the thermal comfort in swine production is the Temperature humidity index (THI) and Radiant Thermal Load (RTL), this, according to Vieira et al. (2010), is one of the ways to assess the responses of the animals to different changes in the thermal environment. Physiological responses can also be assessed by Rectal Temperature (TRectal) and Respiratory Frequency (RF).

Investigations carried out in tropical climates such as Colombia and other countries, evaluating the incidence of construction systems, such as floor types, heating systems, and others, and their influence on environmental variables and physiological responses have been few. Therefore, the objective of the present study was evaluate the thermal environment of both sows and piglets in two different types of farrowing pens in a typological shed in Colombian pig farming, the first using Traditional farrowing pens on a concrete floor (Traditional) and the second farrowing pens on the plastic floor (Slatted), in order to determine the influence on the animal's thermal comfort and its physiological responses.

MATERIALS AND METHODS

Housing and animals

The experiment was carried out in an experimental farm of the Universidad Nacional de Colombia, Medellin campus, located in the San Pablo experimental station in the Department of Antioquia, municipality of Rionegro.

The region is one of the largest pork producers in the Department and in the country. It also has high temperatures and rainfall during the summer, with large thermal amplitudes during the day, which generate more significant problems in controlling environmental variables. The farm is located at an altitude of about 2,100 meters with annual average air temperatures between 12 and 18 °C, annual rainfall of 2,280 mm, and average relative humidity of 75%, with an ecosystem considered as Lower Montane wet Forest (LMwf) in the tropics according to the Holdridge classification.

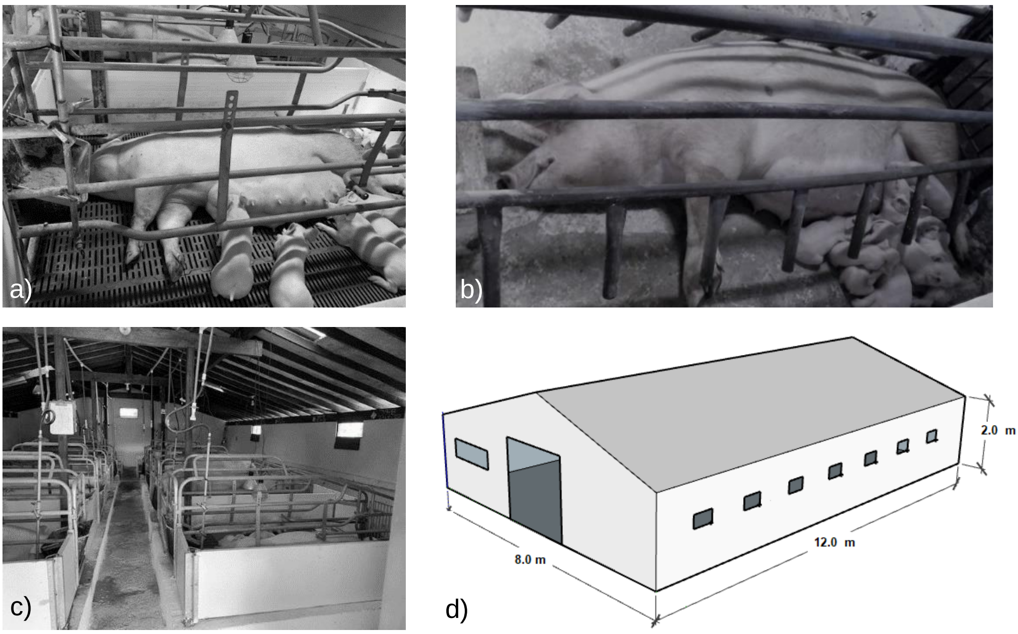

Figure 1. Features of the facility and farrowing pens. a) Slatted, b) Traditional, c) Internal Maternity facility, d) geometry of facility.

The experimental shed is a built-in brick without thermal insulation, with a width of 8.0 meters and a length of 12.0 meters, with a wall height of 2.0 meters. Inside there are 16 Traditional farrowing pens with a concrete floor and heating systems with lamps. Two types of 16 farrowing pens were used in the same installation: One on a concrete floor and heating systems with lamps (Traditional) and another with a Plastic Slatted floor with the same heating systems with lamps (Slatted). The sows were F1 genetic line Hypor Hybrid, female all in their third birth (Fig. 1).

Environmental and physiological responses measurements

Dry-bulb temperature (DBT, °C), black globe temperature (BGT, °C), relative humidity (RH,%) and air velocity (V, m s^{-1}) measurements were taken in each of the 104 points inside the shed, and in each of the farrowings at the piglets and sows height to characterize the thermal environment (Fig. 2). The data were obtained for 24 hours, taking measurements every two hours in each of the farrowing pens and other points inside the shed, with three repetitions for each type of farrowing pen. The measurements began to be taken once the delivery period of each of the pregnant sows ended, and from that moment on, the 24-hour data collection began. All variables were measured manually at equally spaced points on a 1.0×1.0 m grid.

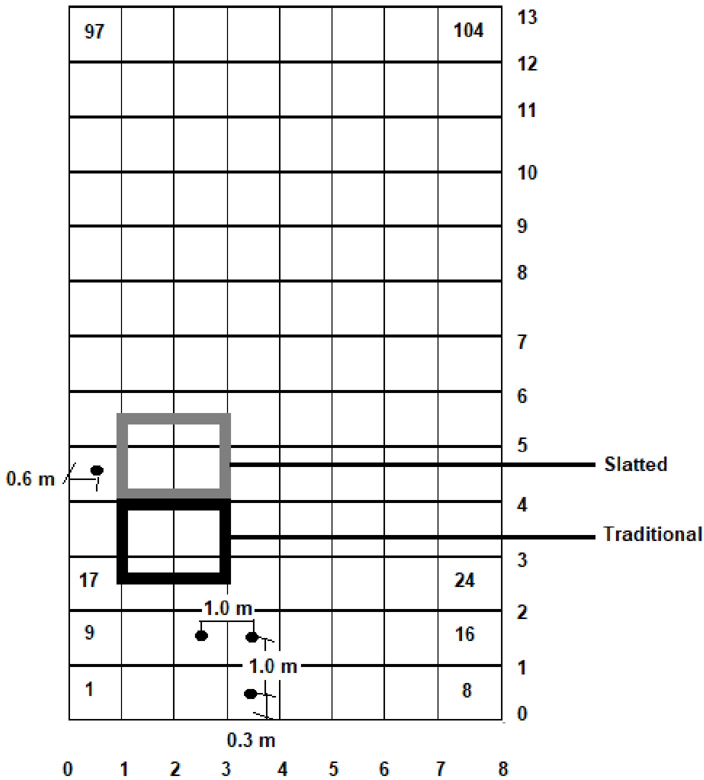

Figure 2. Data collection scheme in the shed.

DBT and RH were measured using a thermo-hygrometer (Extech Instruments®, mod. RHT20, a precision of ±1%), air velocity using a hot-wire anemometer (Extech Instruments®, mod. AN100 e precision of ± 3%), and BGT using a BGT DELTA OHM HD 32.2 Thermal Stress with a precision of ± 0.15 °C.

The Temperature-Humidity Index (THI) and Radiant Thermal Load (RTL) were obtained to characterize the thermal environment from the measured variables. The THI was used to evaluate the thermal environment and was calculated using the equation proposed by Thom (1958):

$$THI = DBT + 0.36DPT + 41.2$$
$$THI = DBT + 0.36DPT + 41.2 \quad (1)$$

where *DBT* – dry-bulb temperature (°C); *DPT* – dew-point temperature (°C).

The RTL (Eq. 3) was calculated using the expression proposed by Esmay (1969), given in W m^{-2}, and the Stefan-Boltzman constant ($\sigma = 5{,}67 \cdot 10^{-8}$ W m^{-2} K^{-4}), and MRT is the mean radiant temperature expressed in K, the V in m s^{-1} and the BGT in K (Eq. 2).

$$MRT = 100 \cdot \left[2.51 \cdot V^{0.5} \cdot (BGT - DBT) + \left(\frac{BGT}{100}\right)^4\right]^{\frac{1}{4}} \quad (2)$$

$$RTL = \sigma \cdot (MRT)^4 \quad (3)$$

Data were collected during the 24 hours with measurements every two hours, during each experimental period in three repetitions to evaluate the animal's physiological conditions, Respiratory frequency (RF), and Rectal Temperature (TRectal). These were measured in the sows and piglets, choosing five at random to obtain the average of the values.

The RF was measured by counting the animals' respiratory movements for 15 seconds, and then the number obtained was multiplied by four to determine the number of breaths per minute. RF was evaluated with a digital stopwatch (± 0.01).

The TRectal was obtained by taking a direct measurement from the rectum of the animals using a digital thermometer (Instrutherm, ± 0.1% precision +0.2 °C).

Statistical Analyses

Statistical analysis was performed using an ANOVA where the means of the values obtained between the two conditions evaluated, the Traditional and the Slatted, both at the piglets and sows' level were compared. The Tukey test was used to compare the means of the response variables of the microenvironments. The statistical analysis of the results was performed using SAS® software (SAS, 1992).

The variables' spatial variations during the experimental period were analyzed by semivariogram fitting and ordinary kriging interpolation. The classic semivariogram was estimated using Eq. 4:

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h]^2 \quad (4)$$

where N(h) – the number of experimental observation pairs; Z(xi) and Z(xi + h) – separated by a distance h.

The semivariogram was fitted using the ordinary least square (OLS) method. The mathematical model used to fit the semivariogram was the linear model, that has been used to monitor the sound emitted by pigs (Borges et al., 2010), and the wave model, which has been widely used in different researches, as described by Gonçalves et al. (2019), but it has not been used for research in animal houses.

The data were interpolated by ordinary kriging. The free software environment for statistical computing and graphics, R (R Development Core Team, 2020), was used for geostatistical analysis and map plotting.

RESULTS AND DISCUSSION

Table 1, shows the temperature and relative humidity results for the two systems, Slatted and Traditional, for both the sows and the piglets. The average temperature values (DBT) during the 24 hours of sampling in the three repetitions did not have significant differences. The average temperature for both the piglet and sow areas in the two systems did not vary significantly, being slightly higher in the piglets' area, as expected. As was determined in other studies such as the one by Machado et al. (2016) using two different types of tiles in farrowing systems, also finding more significant variations in relative humidity and temperature.

Table 1. Climatic conditions of the experimental room

	Dry-bulb temperature (DBT) (°C)*	Relative Humidity (RH) (%)**	Black Globe Temperature (BGT) (°C)***
Sow Slatted	21.4 ± 2.3 [a]	72.7 ± 8.4 [a]	20.1 ± 2.3 [a]
Piglet Slatted	22.6 ± 2.8 [a]	69.1 ± 7.8 [a]	22.3 ± 1.9 [b]
Sow Traditional	20.1 ± 1.8 [a]	82.3 ± 6.1 [b]	20.1 ± 1.8 [a]
Piglet Traditional	20.2 ± 1.9 [a]	85.9 ± 6.2 [b]	19.7 ± 1.6 [a]

*The same letters mean that there are no significant differences (P = 0.125); **The same letters mean that there are no significant differences (P = 0.001); ***The same letters mean that there are no significant differences (P = 0.005).

At all times, the temperatures for the piglets were at adequate levels according to Brown-Brandl et al. (2001) (between 22–30 °C) but not for the sows for which the ideal temperature for gestating is between 12–18 °C. Maintaining stable environmental temperatures as it happens in these conditions is an advantage since high temperatures can increase the respiratory rate, which is one of the most efficient mechanisms for the loss of body heat in swine production (Manno et al., 2006; Kiefer et al., 2009; Baracho et al., 2013).

The Black Globe Temperature (BGT) presented the highest values in the Piglet area in the Slatted system and had significant differences with the other measurements, even though they did not reach values close to the ideal values for the piglets' area that according to Machado et al. (2016) should be above 25 °C, and in the sows, it had values higher than the ideal ones since these should be below 20 °C.

Relative Humidity (RH) for the Slatted system in both the sow and piglet areas was lower than in the Traditional system. According to Do Nascimento Mos et al. (2020), the optimal Relative Humidity values should be between 55 and 75%. Therefore, the Traditional system shows values higher than those recommended, possibly due to damp accumulation on the concrete floors.

Figs 3, 4, show the behavior of the RTL. It was found that in these types of farrowing systems, Traditional and Slatted, the RTL does not reach levels higher than 450 W m^{-2}, which are considered adequate for farrowing systems (Sampaio et al., 2004; Vieira et al., 2010; Do Nascimento Mos et al., 2020). However, there were significant differences between the RTL reached in Piglet Slatted and Sow Slatted ($p = 0.010$), while there were no significant differences between Sow slatted, Sow Traditional and Piglet Traditional. There were significant differences between the Piglet Slatted and Piglet Traditional values, while there were no significant differences between Sow Slatted and Sow Traditional.

The highest RTL values were found in the Piglet Slatted area, most of the time, during the 24 hours of sampling (Fig. 4). However, the maximum values reached in these systems during the 24 hours of sampling, and their repetitions did not reach those reported by Oliveira da Silva et al. (2005), who achieved values higher than 490 W m^{-2} with incandescent and infrared lamps.

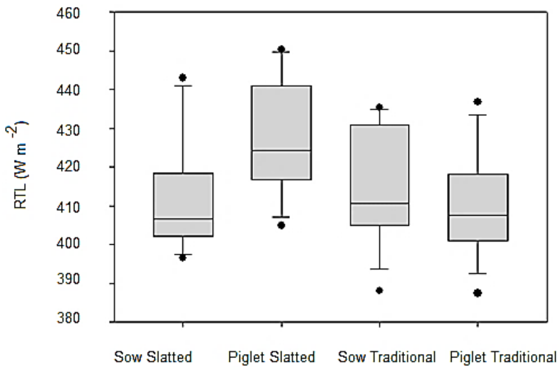

Figure 3. Box plot of RTL (W m^{-2}) for the different farrowing systems.

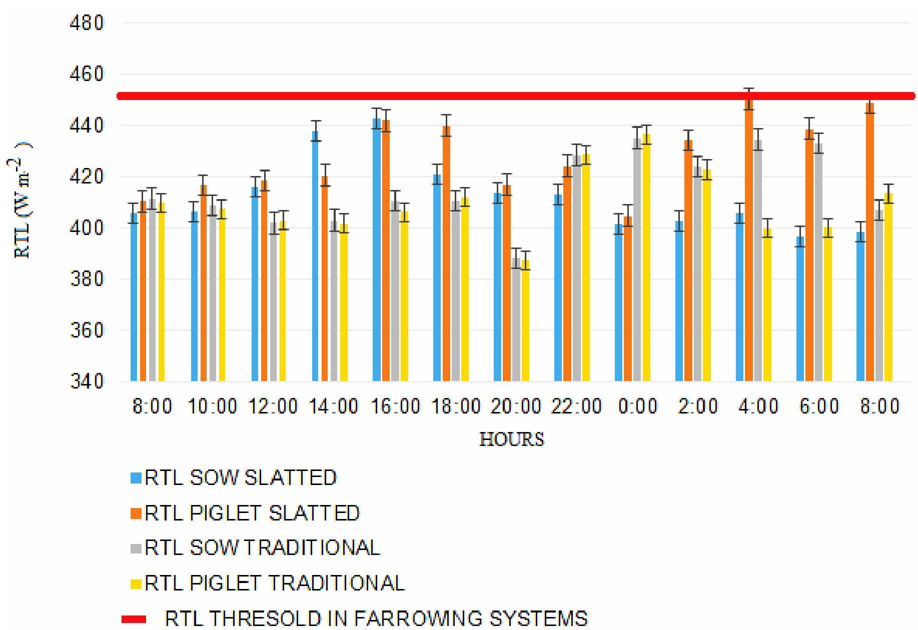

Figure 4. RTL (W m^{-2}) for the different types of farrowing systems for 24 hours.

The THI in the piglets and sows areas in the two systems did not show significant differences (P = 0.160) (Figs 5, 6). All the values in both systems for both piglets and sows' areas presented values greater than 74 most of the time, during the 24-hour sampling of the experiment (Fig. 6), which was determined as the maximum admissible limit for farrowing systems according to Sampaio et al. (2004), Machado et al. (2016) and De Oliveira Junior et al. (2018). However, in the piglets Slatted area, the THI values were slightly higher than in the Traditional farrowing system.

Machado et al. (2016) carried out an investigation with different tiles systems and found significant differences in the THI, with values above the maximum limits for thermal comfort. Therefore, the type of materials used in the infrastructure, especially in the farrowing area, influences its heat transfer properties, as happens in this case, where the concrete floor has a higher thermal capacity than the slatted floor.

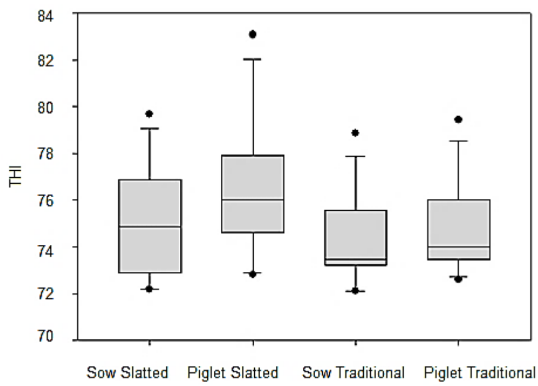

Figure 5. Box plot of THI for the different farrowing systems.

Based on Figs 4 and 6, the RTL and THI data variability during the analyzed time was verified. However, this exploratory analysis did not allow to analyze the homogeneity of the RTL and THI spatial distribution inside the experimental house. The semivariogram and its parameters (nugget effect, C0; contribution, C1; sill, C0 + C1; range, a; and practical range, a') were obtained by fitting different models for RTL and THI (Table 2). In this way, the geostatistical analysis of RTL and THI was used to evaluate the day's variability (Fig. 7).

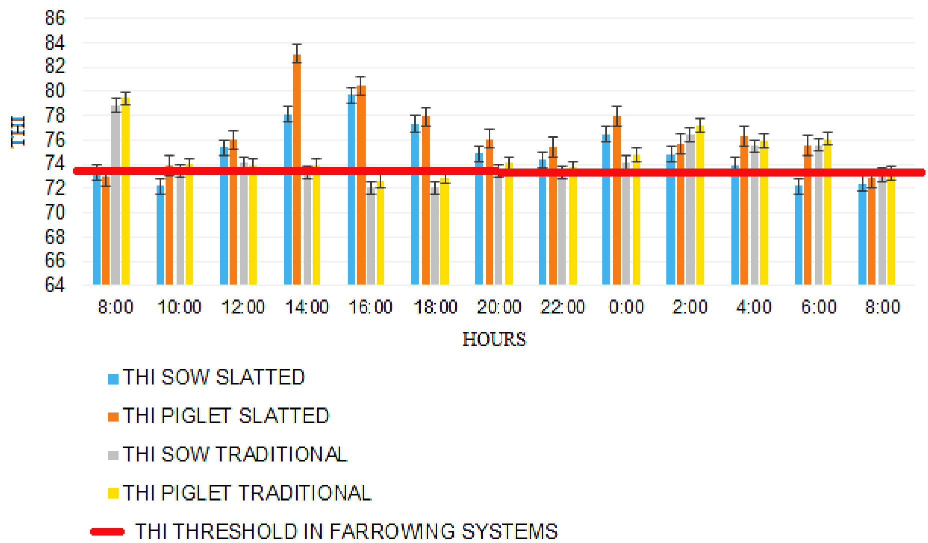

Figure 6. THI for the different types of farrowing systems.

Table 2. Estimated models and parameters of the experimental semivariograms for the RTL and Temperature-Humidity Index in the pig house

	Model	C0	C1	C0 + C1	a	a'	ME
RTL	Wave	203.27	161.95	365.22	1.1051	3.305778	-0.02064
THI	Linear	0.000	0.59	1.00	inf	inf	-0.389

C_0 – Nugget effect; C_1 – Contribution; $C_0 + C_1$ – Sill; a – Range; a’ – Practical range; and ME – Mean error.

Fig. 7 shows the typical spatial distribution of the Radiant Thermal Load (RTL) and Temperature humidity index (THI) of the experimental room. It shows the positions of both farrowing systems within the space. THI in the areas where the farrowing pens are located is between 75–78, being higher in the slatted area as shown in Figs 5 and 6. The THI values increase in other areas of the shed where it reached values greater than 80, possibly because these areas are located near the air vents, so more heat and relative humidity accumulated at the height of the maternity shed. The farrowing area shows an RTL between 410–440 w m^{-2} with slightly higher values in the slatted system. The RTL distribution is almost uniform without significant differences in almost the entire shed area, where there were values between 380 and 415 w m^{-2}.

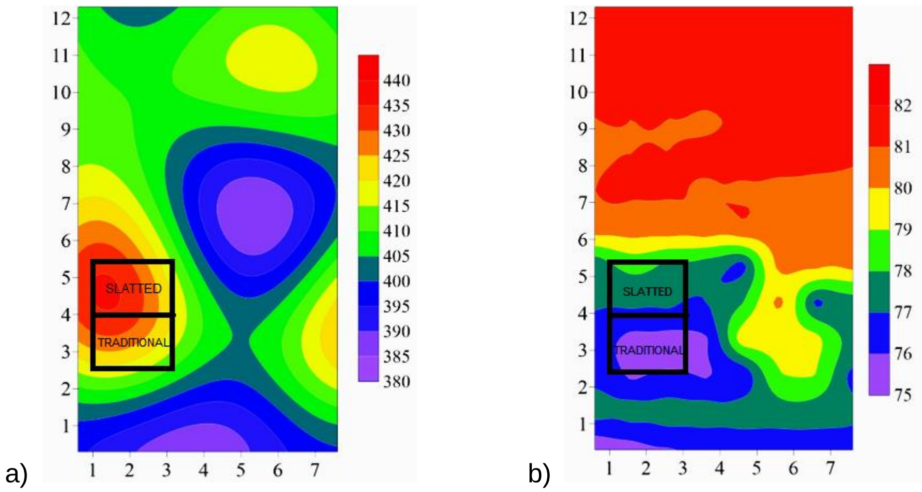

Figure 7. Spatial distribution of the average of a) Radiant Thermal Load (RTL) (W m^{-2}) and b) Temperature Humidity Index (THI) of the experimental room.

These construction typologies show a good distribution of RTL, but not of THI, which could create a low thermal comfort level in most of the major part of the installation, that are similars results found by Philippe et al. (2011).

Table 3 shows the average values of Respiratory Frequency (RF) and Rectal Temperature (TRectal) for the different systems evaluated. According to Vieira et al. 2010), the average values of respiratory rate for newborn piglets are between 50–60 mov min^{-1}, and for sows between 25–35 mov min^{-1}. Therefore, the values found in the different systems for both piglets and sows are within the normal ranges and are similar to those found by Vieira et al. (2010) in sow with different maternity systems (26.48–35.73 mov min^{-1}) and De Oliveira Junior et al. (2011) in piglets (average of 45 mov min^{-1}).

Table 3. Respiratory Frequency (RF) and Rectal Temperature (TRectal) values

	Respiratory Frequency - RF (mov min^{-1})*	Rectal Temperature - TRectal (°C)**
Sow Slatted	24.0 ± 2.9^{b}	38.7 ± 0.7^{a}
Piglet Slatted	50.6 ± 5.9^{a}	38.8 ± 0.4^{a}
Sow Traditional	32.2 ± 8.3^{c}	38.5 ± 0.6^{a}
Piglet Traditional	52.1 ± 7.8^{a}	38.6 ± 0.4^{a}

*The same letters mean that there are no significant differences ($P = 0.001$); **The same letters mean that there are no significant differences ($P = 0.005$).

(The TRectals for both sows and piglets in the two systems remained stable and within average values, and during the 24 hours of measurement, in the three repetitions, they did not have significant changes, which coincides with the measurement found by De Oliveira R.F. et al. (2018) in thermal comfort conditions (average 39 °C).

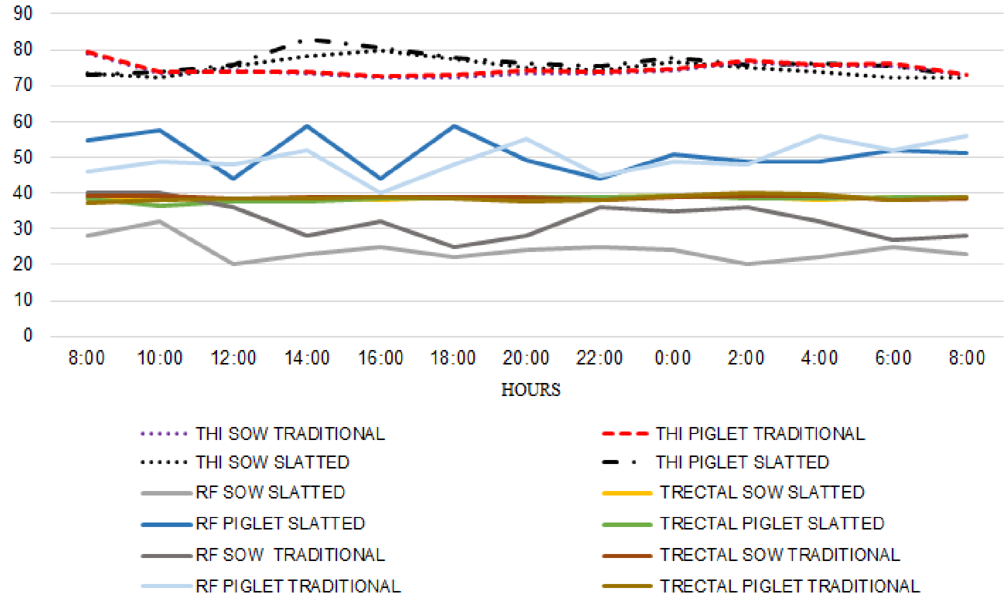

Figure 8. Variation of the RF in Piglets and Sows with the THI.

Unlike the TRectal, the behavior of RF concerning THI had more significant variation throughout the experimental period in the two systems, especially with higher variation peaks between 8:00 and 18:00, both in the piglets and sow's area, being greater in Piglets. This behavior occurred in the two systems without significant differences (Fig. 8). This increase in RF and its variation when there are variations in THI can be a sign of thermal discomfort in the piglet area in the two systems and the sows area, mainly in the Traditional system, wherein some hours of the day, especially in peak hours of maximum temperature between 12:00 and 18:00 hours, the main peaks of variation occurred, and the RF values exceed the permissible limits. These can activate the physiological mechanism of the animal to maintain its homeothermy, such as was described by Renaudeau et al. (2012).

CONCLUSIONS

The evaluation of thermal comfort based on some physiological responses showed that they did not present significant differences in the two systems at the sows' height for the piglets, however between the sows were found significant differences, but conditions were found that did not generate animal thermal comfort for the piglets and sows evaluated through THI. These results show that the type of floor has little impact on the conditions of animal thermal comfort at the sows and piglets' level, being more influenced by the heating system and the building design.

ACKNOWLEDGEMENTS. The authors would like to thank the Universidad Nacional de Colombia, Faculty of Agricultural Sciences ‘Bioclimatica Aplicado a la Agroindustria’ Lab, and San Pablo Swine Experimental Farm in Medellín Campus, and Lavras Federal University - Brazil.

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